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To Problem of Designing of The Landing Radars

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S.B. Makarov[1], M.V. Markosyan[2,3], V.H. Avetisyan[2,3], A.K. Aharonyan[2,3], H.G. Martirosyan[2], R.A. Davtyan[2]

[1] *St. Petersburg Polytechnic University, Polytechnicheskaya str. 29, 195251 Saint Petersburg, Russia*
[2] *Yerevan Telecommunication Institute, Dzorapi str. 26, 0015 Yerevan, Armenia*
[3] *Russian-Armenian University, H. Emin str. 123, 0051 Yerevan, Armenia*

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Abstract: Two structural diagrams for the designing of landing radars are compared. The first diagram of radar construction is based on the use of a single receiving-transmitting phased array antenna that forms a scanning four-beam directional pattern in receive mode and narrow probing beam in transmission mode. The second diagram is the radar with separated receiving and transmitting antenna systems. The phased array antenna is also used as the receiving antenna system. A separate transmitting antenna system consists of a set of separate radiating units, each of which sequentially irradiates its section of the radar coverage area by switching of the transmitter to a choosing unit. The process of searching of an aircraft and measuring its angular coordinates, range and speed in a particular area section of the radar coverage is synchronized with the switching of the microwave probing transmitter signal to the unit wich irradiates this section.

Keywords: Lending radar, transmitting antena system, single recieving-transmitting antena.

1. Introduction

Landing radars are an integral part of the radar equipment of any airport. They operate in the centimeter wavelength range $(\lambda \approx 3.2cm)$, and the angle radar coverage of such radars is about $30^0...35^0$ by course (azimuth) and is $10^0...12^0$ for the glide path (elevation). The range of the landing radar usually does not exceed $30km$. The dispatcher's radar, also of the centimeter wavelength range, operates in the interval of $30...50km$ from the airport, and the surveillance radar of the meter wavelength range operates in the area of $50...80km$. The first provides monitoring of the air situation and the implementation of operational control of aircraft (AC), and the second is used for continuous monitoring of the overall air situation. The reliability of the AC landing in a large degree depends on the characteristics of the landing radar. These are its resolution, the measurement accuracy of the speed, the range and the angular coordinates of the AC, which ultimately are determined the degree of the tracking alignment of the AC and its tracking to the airport runway. On the other hand, the operation speed of the radar determines the speed of data updating about of the air situation in the operation area of radar and the traffic capacity of an airport. The requirement to the extended precision of determining of the AS angular coordinates is satisfied by using the high-precision monopulse method [1], and the radar high speed operation is provided by electronic scanning of beams of the phased antenna array (PhA), which is used in the radar antenna system [2]. However, the reliability of the radar and its manufacture cost bring about the question of choosing of the radar designing structure.

The purpose of given work are the discussion and comparison of two structural schemes for the radar designing and the estimation of their some parameters. The first scheme is designing for the radar with a single receiving-transmitting PhA and the second scheme is – for the radar with the separate receiving and transmitting antenna systems.

2. The landing radars with single combined phased array antenna

The block diagram of that landing radar is shown in fig. 1. The radar has the combined PhA, which is a single receiving-transmitting antenna. In receiving operation mode of the radar, the monopulse method is used for determining of the AC angular coordinates. In the radar transmission mode, the control voltage generator supply the radar transmitter by the group of voltages, which are intended for the formation of probe pulses. Another group of control voltages supply the variable phase shifters and attenuators in the paths of the PhA component antennas for forming of scanning probe beam.

In the PhA reception mode, those phase shifters and attenuators receive the corresponding voltages from the generator for formation of a scanning four-lobe directional pattern (DP). The transition of the PhA from the one operation mode to another is carried out by another group of the generator control voltages which supply the switches in the paths of the PhA component antennas.

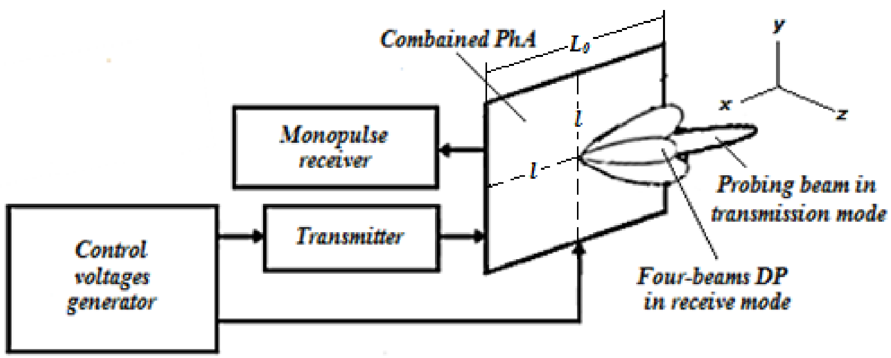

Fig. 1. Block diagram of landing radar with single combined PhA

The two needle-shaped beams of the receiving four-lobe DP, which determine the AC course, are spaced in the horizontal plane and are intersected in the radar boresight at $-3dB$ level. Those two beams scan synchronously and coupled in the angle interval $\pm 17{,}5^0$ by course and $\pm 6^0$ y glide path. Two other beams of the receiving four-lobed DP in the vertical plane, scan synchronously in the same way and determine the glide path of the AC. For determination of AC course and glide path with an accuracy less than a tenth of a degree, the width $2\theta_{0,5}$ f those needle-shaped beams should be $2\theta_{0,5} \leq 1{,}5^0$ t the level $(-3dB)$ [3]. Such PhA can be represented as a sheet with 4 sections $L_0 = 2l$ (e fig. 1), where each of them forms one needle-shaped beam which simultaneously scans with the other three simultaneously formed beams. Taking into account the operating wavelength

$\lambda \approx 3.2cm$, $2\theta_{0,5} \approx 1,3^0$nd efficiency coefficient of PhA $\eta = 0.8$, we will do some estimates by the following relationships [4]

$$\left(2\theta_{0,5}\right)_{x,y} \simeq 57,3 \times 0,888\lambda / l_{x,y} \tag{1}$$

$$G = \eta D = \frac{\eta 4\pi l_x l_y}{\lambda^2} \tag{2}$$

where $l_x = l_y = l$: the linear size of each section of the sheet, $D-$directivity coefficient of one section, $G-$ its gain factor. The estimates show that each section of the PhA should have an aperture equal to $l^2 \approx 1,25 \times 1,25\mathrm{m}^2$ and $G \approx 15340(41,86\text{ dB})$ Taking into account the four-lobed structure of the receiving DP, the PhA will have aperture equals to $L_0^2 \approx 2,5 \times 2,5\text{ m}^2$ and the gain factor equals to $G_0 \approx 30680(44,86\text{ dB})$ Assuming that the four-lobed DP is swinging by the course in limits $\pm 17,5^0$ n the radar coverage area without arising of diffraction maximum, we choose the ratio of the wavelength λ o the distance d_x between component antennas equals to $\lambda / d_x \approx 0,75$ [4]), that is $d_x \approx 2,4\text{cm}$. The number n_x f component antennas along a horizontal in each section of the sheet is defined as $n_x \approx l / d_x = 1,25 / 0,024 = 52$ and accordingly in PhA as $N_x = 104$ Similarly, assuming that the four-lobed DP is swinging by the glide path in limits $\pm 6^0$ n the radar coverage area without arising of diffraction maximum, we choose the ratio $\lambda / d_y \approx 0,84.$ e will have: $d_y \approx 2,7\text{cm}$ the number n_y f component antennas along a vertical in each section of the sheet is $n_y \approx l / d_y = 1,25 / 0,027 = 46$ and accordingly, in PhA $N_y = 92$ The total number N f component antennas (radiators) will be equal to $N = N_x \times N_y \approx 9568$ This means, that we have the presence of corresponding huge number of switching elements, phase shifters, etc. in the paths of the radiators.

3. The landing radars with separate receiving and transmitting antenna system

Block diagram of such landing radar is shown on fig. 2 [5]. The receiving antenna system consists of the PhA operating only in the receiving mode and forming the above described four-lobed DP for providing high-precision monopulse method of measuring of the AC angular coordinates. It is clear, that at the same requirements to the determination accuracies of the AC course and glide path and the same requirements to swinging of the four-lobed DP within the same radar coverage angular area, the receiving PhA will have the same aperture $2,5 \times 2,5\mathrm{m}^2$ gain factor $G_0 = 30680(44,86\text{ dB})$ and the same number of component antennas $N \approx 9568$s estimated above. In turn, this means that the receiving PhA will have the same number of variable phase shifters and attenuators contained in the paths of the component antennas. However, the receiving PhA as opposed to the transceiver PhA of the previous circuit, does not contain switching elements for the operation mode changing. Notes, that the number of such elements is more and amounts to a round sum in monetary unit.

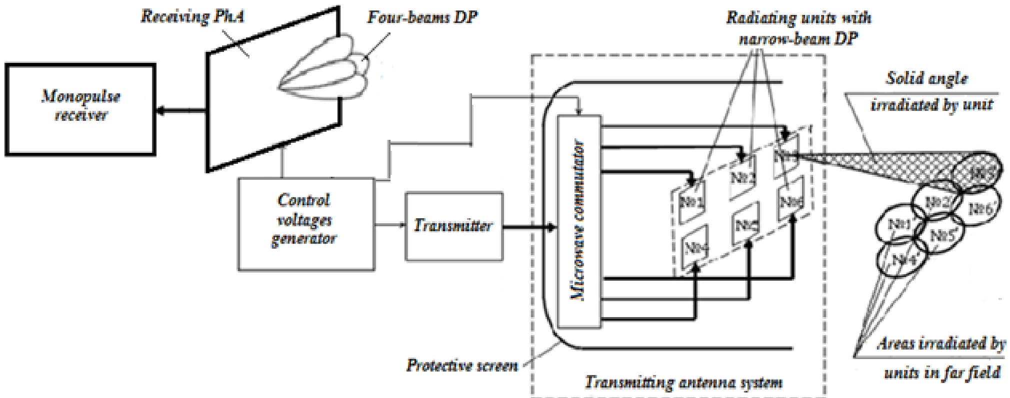

Fig. 2. Block diagram of landing radar with separate receiving and separate transmitting antenna systems

The transmitting part of the antenna system consists of a microwave commutator and a double-row set of identical radiating units, for example, as narrow-beam horns. Each row should be has five units, but for simplifying of the Fig.2, each row has 3 horns as shown in the given figure. Each of these 10 horns has the DP lobe width about $6^0...7^0$. The axes of the horns are located relative to each other by such manner that the irradiated angular solid sectors of the horns are partially superimposed on each other and thereby the whole coverage area of the radar is irradiating at the series excitation of the horns. Thus, the irradiation zone of the transmitting unit is equal to the radar required coverage area. During the operation of a concrete horn, the four-lobed DP of the receiving PhA scans within the irradiated solid angle of this horn for searching of the AC and measuring its coordinates and speed. At the switching the microwave power to another horn, the receiving PhA synchronously switches to the scanning mode in another solid angle corresponding to this horn, similarly functioning already in this area. The commands are carried out by supplying of corresponding voltages from control voltages generator to the microwave commutator and the receiving PhA. Two possible diagrams of implementation of the microwave commutator with the using of the controlled balanced gas-discharge switchers or the controlled gas-discharge full-connection switchers are given in the [5]. Let us estimate some parameters of the landing radar shown in Fig. 2. However, at first note the following. As identical radiating units (see Fig. 2) with the mentioned above narrow-beam lobes of the DP, may be used the radiating PhAs of corresponding apertures, but without variable phase shifters and attenuators. Constant phase shifts between the radiators of each PhA should be chosen by such manner that the main lobes of each of the radiating PhA would irradiate that section of the radar coverage area which was irradiated by the replaceable horn. The use of such phase arrays has the advantage to obtain lower levels of the DP side lobes by using a special amplitude distribution over the sheet of each PhA. The aperture of each radiating PhA should provide a beam with $6^0...7^0$ width. The calculation of such PhA with the value 0.8 of its efficiency coefficient, have carried out according to expressions (1), (2), and at choosing of $\lambda / d \approx 0{,}84$ (d the absence of a diffraction maximum), gives a sheet value of such a radiating PhA $-27 \times 27 cm^2$, gain - $G_T = 716$ $(28.55 dB)$, and the number of radiators -100. Taking into account double-row arrangement of such PhA with 5 pieces in each row, the dimensions of the radiating sheet of the whole transmitting antenna system - $(27\,\mathrm{cm} \times 5) \times (27\,\mathrm{cm} \times 2) = 1{,}35 \times 0{,}54\,\mathrm{m}^2$ Now, let us estimate the average power P_T f the radar transmitter. We assume that the operation maximum range of the radar is $D_{max} \approx 30\,\text{km}$ and sensitivity P_R f its receiving system is $P_R = 10^{-13}\,\text{W}\ (-130dBW)$, which is realized in the centimeter range modern radars. We also assume, that the AC has the average scattering cross section σ equal to $\sigma = 5\,\text{m}^2$.he gain value of the receiving antenna is assumed to be equal to that deduced above - $G_0 = 30680(44{,}86\ \text{dB})$. The estimation of the average power P_T f the transmitter follows from the radar equation [3].

$$P_T = 64\pi^3 P_R D_{max}^4 / \sigma\lambda^2 G_0 G_T \qquad (3)$$

The result is $P_T \approx 1{,}43\,\text{kW}$. At other same values included in expression (3), the power may be reduced by increasing the gain G_T of radiating PhA. However, it is necessary to note that at the same angular coverage area of radar and increasing of G_T k times, the number of PhAs in each row and in each column of the transmitting antenna system will increase in $\sqrt{k}$ mes, and linear dimensions of its sheet will increase in k times. Next, it is possible to avoid the commutation of microwave probing signal from the transmitter to the transmitting antenna system. For this, we can use the single radiating PhA which should scan its main lobe from one section of the radar coverage area to another section in accordance with the given commands. In this case, the additional number of variable phase shifters are necessary in the single radiating PhA.

Thus, the reducing of the radar realization cost requires a complex estimation taking into account both as the discussed above parameters and as much the costs of the units and blocks included in the radar.

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